49 inches at Scopello, and 69 inches at Oropa. The two absolutely largest daily falls occurred on the 5th, viz., 8·9 inches at Crabbia, and 9·1 inches at Mesma. Part iv. of the paper deals with the general causes determining the rainfall of Italy and the application of the results in explanation of the mode of the peculiar distribution of the rainfall over Italy during 1872.

MACMILLAN AND CO. will shortly publish the second part of Mr. Pickering's "Physical Manipulation."

THE annual meeting of the Aëronautical Society was held on the 7th inst., Mr. Charles Brook, F.R.S., presided. A paper was read by Mr. D. S. Brown on the advantage of applying power for aërial propulsion in an intermittent manner, and on the soaring of birds. Another paper by Mr. Armour, C.E., on air compression under wing-planes, was read.

THE fiftieth anniversary of the Société Industrielle de Mulhouse has been celebrated by an Exhibition of the Arts and Manufactures of Alsace. M. Perrot, one of the original founders, read the report, which showed that the Society has had a prosperous and useful career. Papers were read on the electric light, illustrated by the illumination of the banquet hall by electricity; on steam-engines; on borings at a great depth executed in Alsace; on electro-chemical experiments made on benzol. The meeting was a most successful one.

THE following additions have been made to the Royal Westminster Aquarium during the past week:—Young Green Turtle (*Chelonia viridis*) from the Island of Ascension, presented by officers of the *Challenger* expedition; Monk-fish (*Rhina squatina*); Blue and Red Wrass (*Labrus mixtus*); Greater Weever (*Trachinus draco*); Horse Mackerel (*Trachurus trachurus*); Angler-fish (*Lophius piscatorius*); Gattoruginous Blenny (*Blennius gattorugine*); Red Gurnard (*Trigla lyra*); Grey Gurnard (*T. gurnardus*); Streaked Gurnard (*T. lineata*); Lump-fish (*Cyclopterus lumpus*); Sea Lamprey *Petromyzon marinus*); Mud Lamprey (*Ammocœtes branchialis*).

THE additions to the Zoological Society's Gardens during the past week include among others, a Mexican Deer (*Cervus mexicanus*) from S. America, presented by Mr. Thos. B. Forwood; two Spur-winged Geese (*Plectropterus gambensis*) from S. Africa, four Galapagan Tortoises (*Testudo elephantopus*) from the Galapagos Islands, deposited; a Humboldt's Lagothrix (*Lagothrix humboldti*), an Ocelot (*Felis pardalis*), a Tayra (*Galictis barbara*) from S. America; a Great Barbet (*Megalœma virens*), from the Himalayas, purchased.

LOAN COLLECTION OF SCIENTIFIC APPARATUS

SECTION—MECHANICS

PRIME MOVERS [1]

HAVING thus mentioned the earliest record of hydraulic (or indeed of any) prime movers I will not endeavour to trace their history down to modern times, as it would be impossible to do so usefully within the limits of an address. I will therefore now ask you to join me in considering what are the conditions which govern the application of water to hydraulic prime movers.

After all water must be looked upon as a convenient form of descending weight. When the fall is not great it is always practicable by means of water-wheels having buckets which retain the water to employ, as I have said, its mere gravity, and probably it is by this mode that the highest result is procured from any given quantity of water falling through a given height. By the use of a backshot wheel as much as 75 per cent. of the total power is obtainable. The 25 per cent. of loss arises from the friction of the axle of the wheel and of the gearing transmitting the force to the machine which is to utilise it, from some of the water being discharged out of the buckets before the bottom of the fall is reached, from the necessary clearance between the wheel and the tail water, from the eddies produced in the water as it enters the buckets, and (to a certain small extent) from the resistance of the air.

When the difference of level between the source of water and its delivery exceeds, however, 40 or 50 feet, the water-wheel becomes so unwieldy and expensive and revolves so slowly that it ceases to be a desirable prime mover; recourse can then be had to water-pressure engines, engines wherein pistons move in cylinders and being pressed alternately in opposite directions by the head of water set up rotary motion in the machine in the same way as if the pistons were acted upon by steam. In the construction of such water-engines great care must be taken to have ample inlets and outlets in order that the loss, incurred either by the power requisite to drive the water through restricted orifices, or by surface resistance caused by a too speedy flow along the various passages may be a minimum. Care has to be taken also in the arrangements of the valves that the engines, when employed for rotatory movement, may be able to turn their centres without producing an injurious pressure upon the water within the cylinders. Water-engines employed for pumping, but without rotatory movement, are mentioned by Belidor in his "Architecture Hydraulique," published in 1739, article 1,156. In England Sir William Armstrong has brought these machines to great perfection. The first of these, erected many years ago, is still working most successfully at the Allan Head Lead Mines. This machine is driven by a natural head of water and not from an accumulator, and is employed in the mine as a winding engine.

An extremely useful feature in engines of this kind is their adaptability to be driven by the pressure of water derived from an ordinary water-works, and in this manner small manufacturers carrying on business in their own houses are enabled to obtain a prime mover with great ease, and, all things considered, at small cost. Not only is advantage taken of such machines for the purpose of driving manufactories, but water cylinders are now largely employed for working the bellows of church organs, for which purpose an overshot water-wheel is shown as being employed as far back as Solomon de Caus's book, date 1615.

Large water-wheels, or even water-engines, are comparatively costly machines, and as large water-wheels make but few revolutions per minute, they require, as has been said, expensive and heavy gearing to get up speed; thus it is that it frequently becomes a desirable thing to dispense with such machines and to resort to other modes of making available high falls of water. In former times this was done by suffering the impetuous stream of water to beat upon the pallets of water-wheels, but from such machines only a poor effect could be obtained, as a large portion of the energy in the water was devoted to the formation of eddies and the generation of heat, and to the production of lateral currents, leaving but a small percentage available as motive power.

Much of the evil effect, however, attendant upon using the impact of water as a means of driving water-wheels is obviated by the construction invented by the distinguished French engineer Poncelet. For high falls, however, the implement now generally employed is the turbine, of which the well-known Barker's mill may be looked upon as the germ.

I have got before me No. 1,983, a model of Fourneyron's turbine.

This is not an apt model for my present purposes, inasmuch as it is one to be employed with a comparatively low fall of water, but even in such instances the turbine gives most excellent results, and it has the advantage over the water-wheel of being able to work with great efficiency although there may be a considerable rise in the "tail water," a rise which would materially check the action of an ordinary water-wheel. In this turbine every care has been bestowed to give a proper form to the pallets on which the water acts so as to take up step by step as it were the whole of the energy residing in the stream, so that the water may pass away from the turbine in an inert condition, and so that in acting upon the vanes of the turbine, eddies may not be formed and thus energy may not be wasted.

There are probably few sights more surprising to the old-fashioned mechanic, who has been used to see water-wheels of 50 or even 70 feet diameter employed for the utilisation of a high fall, than that of a turbine occupying only a few cubic feet of space but running at such a velocity as to consume the whole of the water of a considerable stream, and so to consume it as to deliver nearly as large a percentage of useful effect as would the cumbrous water-wheel itself.

[1] Address delivered by F. J. Bramwell, C.E., F.R.S., one of the vice-presidents of the Section, May 25. Continued from p. 141.

If the object is merely to raise water this can be done without the employment of either water-wheel or turbine. When a small quantity is required to be raised to a considerable height the Montgolfier ram is employed. No. 1,996, which I have before me, is a glass model of such a ram, but I fear it is too small to be visible, except to those who are very near to the table. You are, however, all aware that the principle of action consists in the sudden arrestment of a column of water flowing with a velocity due to the head. The water on being arrested performs two functions, a small portion raises an outlet valve, and thereby passes into an air-vessel against a pressure competent to drive the water up to the desired height; while the main body recoils along the supply pipe; then, the escape valve having opened the water that has recoiled, returns, a large portion passes out of the valve, and thus the velocity being fully established the escape valve shuts and causes another arrestation and a repetition of the working. This is an implement by which a large volume of water coupled with a low fall, can be made to raise a portion of itself to a great height. But there is a converse use of water, wherein the employment of a small stream of water moving rapidly (owing to its having fallen from a considerable height) is caused to induce a current in other water and to draw it along with itself at a diminished velocity but still with a velocity competent to raise the united stream to a less height, and in this manner many swamps and marshy lands have been drained.

This employment of the induced current as a prime mover is described by Venturier in the record of his experiments made at the latter end of the eighteenth century, and within the last few years Mr. James Thomson has applied the same principle with great success in his jet pump.

The next mode I shall notice of obtaining motive power from water, is also one where it operates by an induced current; this is the "Trombe d'eau," an apparatus wherein water falling down a vertical pipe, induces a current of air to descend with it. The lower end of the vertical pipe being connected with the upper side of an inverted vessel, the bottom of the sides of which vessel is sealed by a water joint, then the water dashing upon a block placed below the mouth of the pipe, is separated from the air, so that while the water descends and escapes from under the sides of the vessel, the air rises and accumulates in the upper part from whence it can be led away to blow a forge fire. These machines are described in Belidor's work.

The utilisation of the rise and fall of the tide is also fully described by Belidor, who gives drawings of channels so arranged that during both the rise and fall of the tide the wheel, notwithstanding the reversal of the currents, revolves in one and the same direction. The tide is a source of power which it is highly desirable should be utilised to a greater extent than it is; if we consider the enormous energy daily ebbing and flowing round our shores, it does seem to be a matter of great regret that this energy should be wasted, and that coal should be burnt as a substitute.

The last mode in which power may be obtained from water, to which I have to allude, is that of the employment of the waves.

Earl Dundonald, better known as Lord Cochrane, proposed by his patent of 1833 to utilise this power for propelling a vessel; this he hoped to accomplish by the use of cylinders containing mercury, the oscillations of which were to cause a vacuous condition in the cylinders, and thereby give motion to an air-pressure engine. Lately we have had produced before the Institution of Naval Architects, and also before the British Association at Bristol, the apparatus of Mr. Tower, by which the motion of the waves is to be utilised; a model constructed on this principle has driven, it is said, a boat against the wind at some two or three miles an hour.

The next kind of prime-movers in order of date to be considered, are those that are worked by the wind.

Although undoubtedly the propelling of a ship by sails, and even the winnowing of grain, must have long preceded the invention of a prime mover driven by water, yet the employment of the wind as a source of motive power for driving machinery, appears to be but of comparatively recent date. It is said that the knowledge of this kind of prime mover was communicated to Europe by the Crusaders on their return from the East, but it is difficult to see what foundation there is for this statement. It appears to be certain, however, that wind-motors were commonly employed in France, Germany, and Holland in the thirteenth century.

We can easily understand that in countries where water falls in quantities and rapid streams are abundant, the windmill would not, owing to its uncertainty, be resorted to; on the other hand, in inland countries and in countries like Holland, where the streams are sluggish, and where there is a large amount of land to be drained, the wind, although still uncertain, would nevertheless be a valuable power, and therefore would be utilised.

Prime movers to be worked by the wind appear to have been made practically in only two forms, viz., the common one, wherein a nearly horizontal axle carries four or more twisted radial sails, and that one wherein the axle is vertical and the arms project from it laterally either as radial fixed arms, as curved fixed arms, or as arms having a feathering motion similar to that of paddle-wheels. Where the arms are straight and fixed, some contrivance must be resorted to to obtain a greater pressure of wind on one side than on the other.

Bessoni, in his work "The Theatre of Instruments and Machines," published at Lyons in 1582, describes a windmill with vertical spindle and curved horizontal arms, placed in a tower with a wind-guard, and by the drawing shows it working a chain-pump. Belidor also says in Article 852 that windmills with vertical axles were well known in Portugal and in Poland, and he describes how that they work within a tower the upper part of which was fitted with a movable portion to act as a screen to one side of the mill.

I will not detain you by an allusion to the sailing chariot mentioned by my Uncle Toby in "Tristram Shandy," nor will I pause to describe the very modern one, that is to say, not more than about thirty years old, which was employed upon Herne Bay Pier. In fact this Exhibition gives but little encouragement to pursue the subject of prime-movers worked by wind, as I have not as yet come across in the Catalogue any apparatus illustrative of the subject.

It is to be regretted that the use of this kind of prime mover, the windmill, is on the decline. It is a power that costs nothing; the machinery can be erected in almost any situation; and although such a motor cannot by itself be depended on, being of necessity "as uncertain as the wind," it nevertheless might be commonly employed as an auxiliary to steam-power, diminishing the load upon the engine in exact proportion as it was urged by any wind which might happen to blow.

I may say, to the credit of our American brethren, that they employ on their sailing-ships a windmill known by the sailors as "The Sailor's Friend," to pump, to work windlasses, and to do all those matters which in a steam-ship fall to the lot of the donkey-engine and steam winch, unless, as in a recent voyage in which all Englishmen have been so much interested, these duties were imposed upon the baby elephant.

There is one motor which may be put either into this class or into the next, where we consider the application of heat; I allude to the smoke-jack, but beyond recognising its existence as a prime mover, and a very early one indeed (it is to be found in Zoncas' work published in 1621), attention need not be bestowed upon it.

We now come to consider those prime movers which are worked by the immediate, and not by the secondary, action, of heat.

The direct rays of the sun have, for a very long time past, been suggested as a means of obtaining motive power. Solomon de Caus in his work, published in 1615, describes a fountain which is caused to operate by the heat of the sun's rays expanding the air in a box and expelling thereby, through a delivery valve, the water from the lower part of the box. When the sun's rays have been withdrawn, the air, cooling, contracts a suction valve, opens and admits more water into the box to be again displaced on the following day. He also gives a drawing of an apparatus where the effect of the sun's rays is to be intensified by a number of lenses in a frame. Solomon de Caus proposes these machines as mere toys to work an ornamental fountain, but Belidor, by Article 827, describes and shows a sun pump consisting of a large metallic sphere, fitted with a suction pipe and valve, and a delivery pipe and valve and occupied partly by water and partly by air, the suggestion being as in the case of Solomon de Caus, that the heat of the sun in the daytime expanding the air should drive up the water into a reservoir, while the contraction of the air in the night-time should elevate the water by the suction pipe and recharge the sphere for the next day's work. In modern times, as we know, some attempts to obtain practical motive power from the direct action of the sun have been made, and notably by Capt. Ericsson.

The temptation to endeavour to bring into practical use a machine of this character is very great. We were told by our

President, in a lecture delivered by him to the British Association at Bradford, that the solar heat, if fully exercised all over the globe, supposing that globe to be entirely covered with water, would be sufficient to evaporate a layer 14 feet deep of water per annum. Now assuming 10 lbs. of water evaporated from the temperature of the air into steam by the combustion of 1 lb. of coal (a much larger result than unhappily is got in regular work), this would represent an effect obtained from the sun's rays on each acre of water equal to the combustion of 1680 tons of coals per annum, or to about 92 cwt. of coal per acre per twenty-four hours; or enough to maintain an engine of 200 gross indicated horse-power day and night all the year round. When, however, we consider the effect of the sun, not upon the surface of water but upon the earth, and deal with its power of producing heat-giving material, the result compares very unfavourably with the work done by the sun itself; and this, no doubt, arises first, from the fact that the sun is frequently obscured, and second, from the fact that a large portion of the energy of the sun is spent in evaporating moisture from the ground, and not in the direct production of combustible material. I have found it extremely difficult to obtain any reliable data as to the weight of fuel grown per acre per annum. If we take the sugar cane, we find that in extremely favourable cases as much megass and sugar together are produced as would equal in calorific effect about five tons of good Welsh coal. Coming to our own country and dealing with a field of wheat, the wheat and straw together may be taken as being equal probably to about two tons of coal as a maximum. The statements made to me with regard to the production of timber per acre per annum, when grown for the purpose of burning, are very various; but the best average I can make from them is that in this country there is produced as much wood as is equal in calorific effect to about $1\frac{1}{2}$ tons of good coal per acre. Comparing these productions of heat-giving material with the energy of the sun, as shown in the evaporation of water, one shows how tempting a field is that of the direct employment of the solar rays as a source of power; more especially, when it is remembered that those rays are obtained from week to week, and year to year, without having to wait the tardy growth of the fuel-destined tree.

I will now ask you to consider with me the prime movers that owe their energy to the heat developed by the combustion of some ordinary kind of fuel—coal or wood. Passing by as a mere toy and not an actual prime mover, the reactionary steam sphere, the eoliopile of Hero, I will come at once to those simple forms of heat-engine (whether worked by steam or the expansion of air), by which water was to be raised. Solomon de Caus, in his work of 1615, already mentioned, says that if you fill a globe with water and have in its upper part a pipe dipping nearly to the bottom, and if you put the globe upon the fire the heat will cause the expansion of the contents, and the water will be delivered in a jet out of the tube.

The Marquis of Worcester in his "Century of Inventions," published in 1659, makes, as is well known, a similar proposition, but it does not appear that these machines were seriously contemplated for practical use. Papin (I take Belidor's Article No. 1,276 as my authority) in 1698 (as appears in his pamphlet of 1707) experimented by order of Charles the Landgrave of Hessen Cassel with the view of ascertaining how to raise water by the aid of fire. But his experiments were interrupted and he did not resume them until Leibnitz, by a letter of Jan. 6, 1705, called his attention to what Savery was doing in England, sending him a copy of a London print of a description of Savery's engine. This engine, which of course is well known to you, is illustrated by a model in this collection, and now on the table before me. Savery employed a boiler, the steam from which was admitted into a vessel furnished like the sun-pump of Belidor with a suction pipe and clack and a delivery pipe and clack; the steam being shut off, cold water was suffered to flow over the vessel, a vacuum was made and water raised into the vessel, which was expelled out of the delivery pipe upon the next admission of steam, the cocks being worked by hand. This machine came into very considerable use and was undoubtedly the first practical working steam-engine. It had, however, the defect of consuming a large quantity of steam, as the steam not only came into contact with the cold vessel but also with the surface of the water in that vessel. Papin, as we know, obviated a portion of this loss by the employment of a floating piston placed so as to keep the steam from actual contact with the surface of the water.

We have in the collection, No. 2,007, a cylinder from Hessen Cassel, said to be of the date of 1699 and to have been intended for employment in Papin's machine, but it is difficult to say for what part of the apparatus it could have been designed, inasmuch as the cylinder is provided with a flange at one end only and no means, so far as I can ascertain, exist for closing the other end. You will see from the diagram that which no doubt is already well known to you; Papin did not propose to condense the steam, and by its condensation to "draw up" the water (to use a familiar expression) but intended that the vessel should be charged by a supply from above, and, that the steam should be employed only to press on the floating piston and to drive the water out. Papin, however, hoped to use his engine, not merely as a water-raiser, but as a source of rotary power by allowing the water to issue from the air vessel, so as to impinge upon the pallets of a water-wheel and thus produce the required revolution.

(To be continued.)

SCIENTIFIC SERIALS

American Journal of Science and Arts, May.—Mr. Holden here collates various observations made on nebula M 17 (the figure of which is like that of a Greek capital Omega) from 1833 to 1875. The drawings show that the western end has moved relatively to its contained stars, and always in the same direction. It may be a veritable change in the structure of the nebula itself or the bodily shifting of the whole nebula in space.—Mr. Trowbridge states that the application of thin plates of soft iron on the poles of two straight electro-magnets, with bundles of fine iron wires for cores, increases the strength of the spark at the poles of two secondary coils surrounding the electro-magnets, 400 per cent. The length of the spark is increased 100 per cent. (but this is only manifested by using Leyden-jars of large capacity with the secondary circuit). Instead of distributing the fine wire of a Ruhmkorff coil on a straight electro-magnet, as at present, it should be distributed equally on two straight electro-magnets whose poles are provided with armatures of bundles of thin plates of soft iron.—Mr. Wilson having applied infusorial earth to land sown in wheat, afterwards treated some of the wheat straw with nitric acid, and found that the siliceous remains consisted almost wholly of the shields of diatomaceæ, the same as found in the infusorial earth (only the larger discs, in their perfect form, being absent). It would appear that simple or compound silicates are useless as fertilising agents, and that silica can enter the plant only in the free state.—In the first portion of a paper on the solid carbon compounds in meteorites, Mr. J. Laurence Smith, after noting that in carbonaceous meteorites the mineral constituents are mainly the same as in the so-called common type of meteoric stones (viz., olivines, and pyroxenes, differing only in the more or less compact form of these minerals), shows, that even in the carbonaceous constituent they are strongly linked even to the iron meteorites.—Mr. Fontaine continues his account of the conglomerate series of West Virginia; Mr. Dana describes new forms of staurolite and pyrrholite; and we also find chemical notes on phosphorus oxychloride, and the oxydation product of glycogen with bromine, silver oxide, and water.—A simple and very accurate method of testing the unison of two forks is (according to Mr. Spice) by holding them *together* over their proper resonant column; if the forks be *very* nearly in tune, beats will be perceived succeeding each other at long intervals, or the sound will merely swell out again very slightly after it has nearly died away. When the forks are absolutely alike, there will be a gradual decrease of sound down to silence, without any reinforcement at any time.

THE *American Naturalist* for May commences with an article by the Rev. S. Lockwood, on Animal Humour. Prof. Asa Gray writes on Wild Gooseberries. Hon. J. D. Cox describes multiplication by fission in *Stentor mülleri*. An article on Primitive man follows, after which Mr. A. S. Packard, jun., describes and figures the Cave-beetles of Kentucky. Prof. Farlow writes on University Instruction in Botany. General Notes and a few short reviews follow, the number being completed by notes and notices of meetings.

Zeitschrift der Oesterreichischen Gesellschaft für Meteorologie, March 1.—This number contains a long article on the relations of temperature and moisture in the lowest atmospheric strata during the formation of dew, by Dr. R. Rubenson, of Stockholm. Observations made by Dr. Hamberg, at Upsala, on temperature at different heights on frosty nights led him to conclude that in the lower strata temperature increases with height, and that the